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In-House Technical Memorandum
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PRELIMINARY STAGES FOR INTEGRATED TEXT AND LINE DRAWING INFORMATION EXTRACTION

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/s/
CHARLES G. MESSENGER
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JOSEPH CAMERA, Chief
Information & Intelligence Exploitation Division
Information Directorate

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6. AUTHOR(S)

Jessica Stanulevich

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

AFRL/RIED
525 Brooks Road
Rome NY 13441-4505

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AFRL/RIED
525 Brooks Road
Rome NY 13441-4505

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Jessica Stanulevich performed this research while employed by AFRL under the summer internship program.

14. ABSTRACT
This paper presents research by a college-bound student during her summer job. The project involved experimenting with a piece of commercial image processing software, analyzing line drawings with associated text towards the ability to recognize the semantic content of editorial cartoons. The goal of this summer project was to initiate the research to enable the recognition of full, frontal faces in simple line drawings.

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1.0 *INTRODUCTION TO PIXCAVATOR*

Pixcavator is an image processing software that locates objects in the image and creates a contour around it which can be edited by the user. An excel sheet is then created, containing data regarding several attributes including size, location, contrast, and roundness. This program has meaningful applications in areas such as microscopy, medical image analysis, cell counting, and image manipulation.

2.0 PROJECT RELEVANCE TO AFRL

For our purposes, we look to use Pixcavator for a project involving integrated text and line drawing information extraction. In the future we hope this program will be able to aid in the analysis of political cartoons. The goal of the research is to manipulate a program that will recognize pictures of people and their facial expressions. This will be done using information about facial components and facial perspective, along with other features such as clothing. This information will be combined with text analysis from the meta-text of the political cartoon. If the temperament and political climate of communities can be discovered through analysis of foreign political cartoons using programs such as Pixcavator, this technology will be able to help the Air Force predict violent uprisings. Line drawing analysis programs will prove useful when dealing with mass quantities of foreign cartoons.

3.0 MY WORK WITH PIXCAVATOR

With my time at the Air Force Research Laboratory, I have helped with the beginning stages of research for the integrated text and line drawing analysis project. With Pixcavator, my goal was to experiment with the program and to be able to recognize full, frontal faces in simple line drawings.

Upon opening the program, there are three main tabs; Analysis, Tools, and Output. Under the analysis tab, you can browse your files to find a supported image file to be analyzed. The image appears on the left and it may be shrunk to speed up the analysis process. The RGB channel that you wish to be analyzed can also be chosen here. Choosing the color channel (red, green, or blue) that you wish to be analyzed allows for that channel to be analyzed separately. This was not important in my project which solely involved black and white line drawings, but it has useful implications when considering color images used in areas such as microscopy. Hitting the “run” button starts the analysis, and brings you to the Output tab where the data is displayed.

Under Tools there are several image-processing options. Brightness, contrast, hue, and saturation may all be changed by adjusting the sliders on the left in order to enhance the image. There are also several other filters and effects that are used mainly for artistic effect. Some of these filters include sharpen, noise, and blur.

The Output tab is the most important. Here the program outlines the dark objects in a red contour and the light objects in a green contour. The user can adjust the contours with the sliders below the image. Thresholds for items such as size and contrast may be adjusted. Once the contours are set, you can view and export the data that it collected on the selected objects. This data consists of whether the object is light or dark, the object's location of the center of mass, size (area), perimeter, roundness, maximum and minimum level of gray, average contrast, and dimensions.

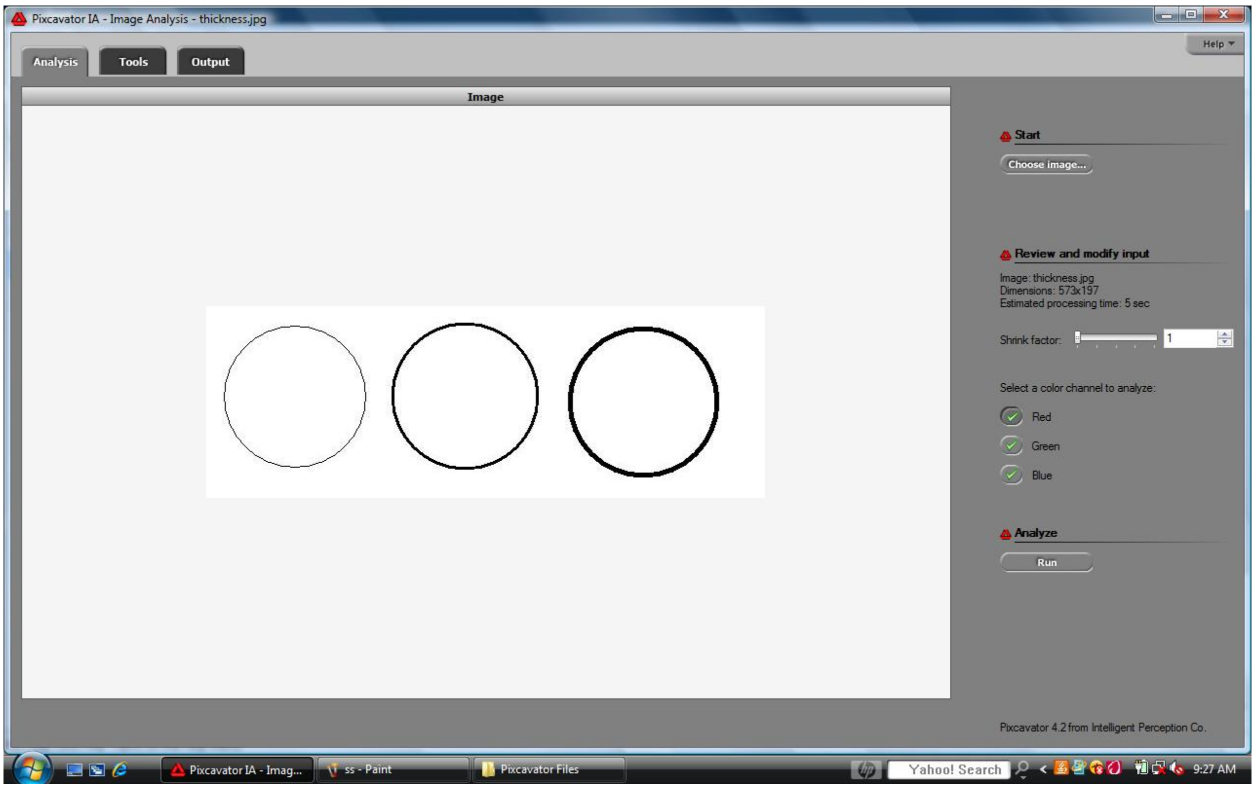


Figure 1. Screen shot of Pixcavator's Analysis tab

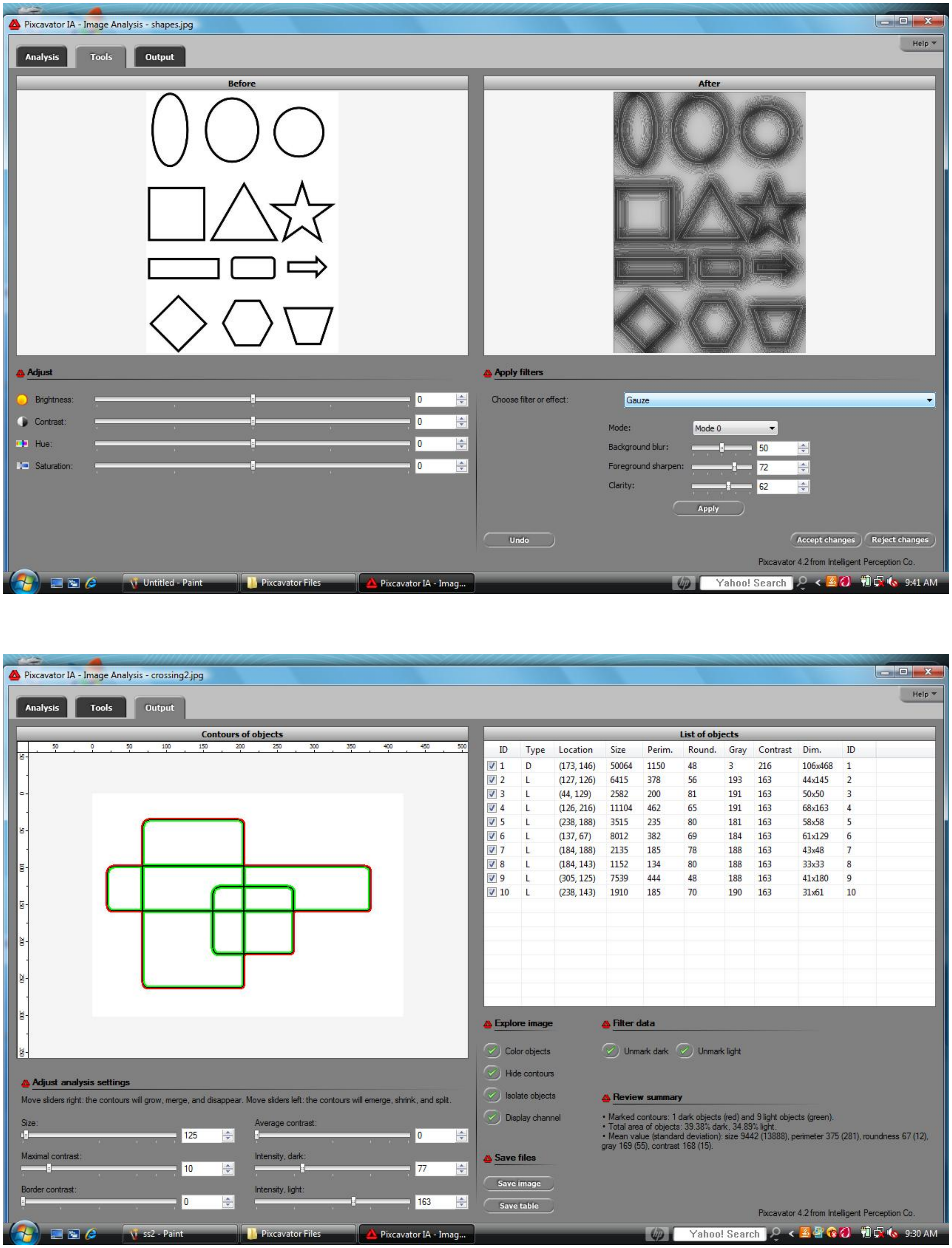
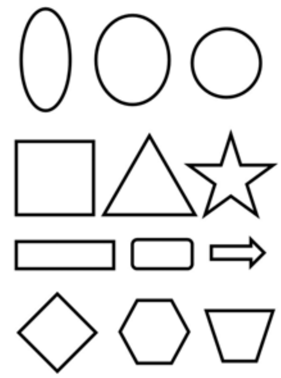


Figure 2. Screen Shot of Pixcavator's Tools tab and Screen shot of Pixcavator's Output tab



The first image I analyzed with Pixcavator was one that I created on Microsoft word. It consisted of twelve different shapes including an elongated oval, oval, circle, square, triangle, star, rectangle, rectangle with curved edges, arrow, diamond, hexagon, and trapezoid. After looking over the collected data, it was clear that the roundness data attribute would be helpful in future research. This attribute was a distinguishing characteristic that could aid in recognizing an object as a head. The two most head-like shapes, the circle and the oval, were listed in the data as having the highest roundness, 90 and 88, respectively. Looking only at the information on the chart that Pixcavator has provided us with, and knowing that the objects with the highest roundness values were head-shaped, one could easily distinguish that, for example, an object with a roundness value of 25 would not be a head. In the collected data, the item with roundness 25 was the star.

In the second analysis, I created an image with circles and ovals and added eyes and mouths; three simple faces. The mouths, although simple, varied. One was frowning, one smiling, and the third was a straight line. When analyzed, Pixcavator created twelve contours (around each head, eye, and mouth), and found data on each of these shapes. In order to differentiate between the head, eyes, and mouths, scaling and sizes became important. In this simple figure, when looking only at the data provided from Pixcavator, each data point can be matched up to the object it functions as in the picture. The heads and eyes (nine objects) have a much higher roundness value than the three mouths (40, 36, and 16; versus 80+). Looking at the nine objects of high roundness, the data attributes of size, perimeter, and dimensions easily distinguish between what is a head and what is an eye; the larger object being the head. Location, which provides the center point of the item, allows the user to determine which eyes, mouth, and head belong together.

Other tests that I did with this software included seeing if the thickness of a line could be discovered from the program, testing with overlapping lines, testing a circle with a line extending from it, testing a circle with a line separate from it, examining a shape with excess scratch pixilation, analyzing a hand drawn circle, analyzing a hand drawn circle that was not completely closed, and testing the hand drawn circle with other shapes crossing and extending from it. These experiments were mainly executed to gain a better understanding of the software.

In the first test, the software created a dark contour around the outside of the image, and a light contour inside of the image. By comparing the dimension attributes of the two, it was found that thickness can be discovered by using only Pixcavator data. In images with overlapping lines, one dark contour was created around the entire image, and several light contours were created for each inner piece. For example, in a classic Venn diagram image, there is one dark contour and three light contours. In the image of a circle with a line extending from it, one light contour surrounded the circle and one dark contour surrounded both the circle and the extending line. In the dark contour, the location, or center of mass, was shifted slightly to the direction from which the line extended. In the image of the separate circle and line, there was one light contour around the inside of the circle, and two dark contours, one around the circle and one around the line. This shows that Pixcavator has the ability to detect individual lines.

In another analysis, a circle was drawn and impurities were added to the image. In real situations, all images will not be perfectly clean. The results of this test were favorable to our research, as the default settings of the size threshold allowed for the program to ignore the excess pixilation so that no unnecessary marks were included in the data. When a hand drawn circle was analyzed, in comparison to a computer generated circle, the results were strikingly similar. As predicted, the roundness was lower, but not by much. The dark contour roundness was 85 as compared to 90, so the ability to pin the shape as a circle based on the roundness data was not lost. In the next test, a hand drawn circle was again used, except the circle was not connected; there was a gap in the image. The data table that resulted from this analysis had no light contour, and a dramatically different dark contour. The program recognized the unfinished circle as a line, and therefore all the resulting data was produced as if the object was a line rather than a circle. This significantly affected the dimensions, increased the perimeter, and decreased the size (area). Also, instead of having a roundness of 80+, the most important distinguishing factor of a circle, it had a roundness of two. If the political cartoon artist has more of a sketchy style with gaps in his drawings, it would be difficult to locate faces with Pixcavator. I spent time researching if an algorithm could be applied to this dilemma, but because no endpoints were given, a visible solution has not yet presented itself. There is no way to differentiate between data of a line, data of an unfinished circle, and data of an arc.

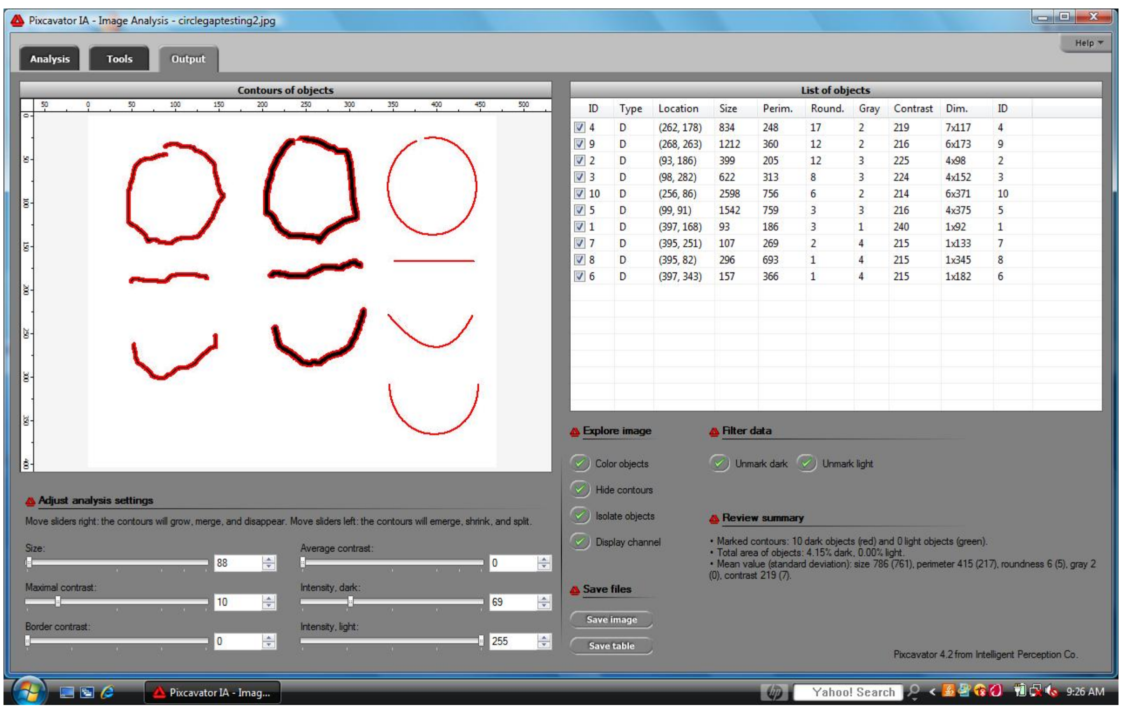
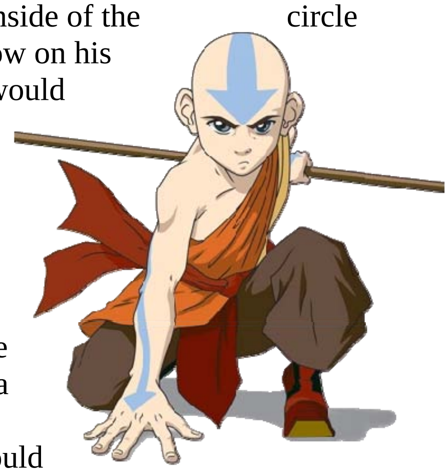


Figure 3. Trying to determine from the data if an unfinished circle can be detected.

Another image that I analyzed with Pixcavator was one that combined elements from various tests. This image consisted of a hand drawn circle with lines and other shapes extending from it and a triangle crossing through it. The contours appeared as expected, one dark contour surrounded the entire image including the extending lines, and the light contours appeared inside all of the individual shapes. However, I noticed that the triangle that crossed into the circle significantly decreased the roundness of the circle (roundness was decreased by about 30). This creates a problem for indentifying heads if the character were to have some form of distinguishing trait on their head. This situation of the triangle inside of the circle caused me to think of Aang, a cartoon character who has an arrow on his forehead. If he were to be analyzed with Pixcavator, the arrow would decrease the roundness of the head to a point where it would be extremely difficult to gather from the data which object is his head. We have to look for ways around this. For example, in the case of Aang, we could look to locate the arrow instead of a head, and from the coordinates and size of the arrow, the head and other facial features could be located.



Based on this research, one could theoretically determine if there are faces in a simple image, and be able to match up data points to their corresponding facial features using the following process. After securing a contour around the image, the data should be organized by roundness. An object with high roundness (about 80+), with a large size attribute, and whose dimensions are similar would be a head. Two objects with high roundness, approximately the same y coordinate, around the same size, and much smaller in comparison to the head would be the eyes. An object with coordinates near the eyes on the x scale, but lower on the y scale, while remaining inside of the face would be the mouth.

While no exact conclusions were made with my time at AFRL, progressions were made and my work can be built upon. Basic work from these simple line drawings will lead to work with detailed faces and pictures. In the future, we will look towards recognizing real stylized cartoon faces. A cartoon with its own style will be selected and analyzed with the goal of recognizing which shapes are faces, then recognizing the characters that are represented. The meta-text (title, artist, text under the drawing) and the integrated text will be relevant and important to understanding what is presented in a cartoon.

4.0 VARIOUS OTHER SUMMER WORK

Before working on the Pixcavator project, I created a personal twiki page. This is a great way to facilitate communication between employees. If all AFRL employees were to create pages, then this would be a great directory for employees to use to obtain information such as e-mail addresses and phone numbers. If they chose to post one on their twiki page, a photograph would greatly help new employees match names to faces.

I have picked up new skills on programs such as Microsoft Word. I believed that I knew all the tricks of this program, but Sharon helped me discover how to use an automated table of contents, and the ability to make each item function as a link and bring you to where it is located in the document.

5.0 IMAGE ANALYSIS SOFTWARE CHART

I researched some current image analysis software that is available in order to gain a better understanding of this area and what such programs are capable of.

TABLE 1. IMAGE ANALYSIS

Name	Website	Source	Cost	What it does	What it does to text
Able Image Analyser	http://able.mulabs.com/	Mu Labs	$100	Automatically detects images and provides dimensional measurements (distance, area, angle, point, line, pixel profile, histogram) in a spreadsheet	No mention of text analysis.
AxioVision	http://www.zeiss.de/axiovision	Carl Zeiss	Contact for quote	Specifically designed for scientific microscopy	No mention.
BioImage Suite	http://www.bioimagesuite.org/	Yale University	$0	Image visualization and registration, surface editing, cardiac 4D multi-slice editing, diffusion tensor image processing, mouse segmentation and registration	No mention.
CellProfiler	http://www.cellprofiler.org/	Broad Institute Imaging Platform	$0	Cell image analysis software designed for biologists, can be trained to recognize phenotypes	No mention.
Clemex Vision PE	http://www.clemex.com/Products/ImageAnalysis/Software/VisionPE.aspx	Clemex Technologies	Find quote online	Measure grain size, count particles	No mention.

Digimizer	http://www.digimizer.com/	MedCalc Software	$395	Automatic object detection, measurements of several characteristics, print save or export measurements to a spreadsheet, filters	No mention.
Image Pro Plus	http://www.mediacy.com/index.aspx?page=IPP	Media Cybernetics	Request info. online	2D and 3D image processing, enhancement, and analysis software with extensive measurement and customization features	No mention.
Image Warp	http://www.imagewarp.com/	A&B Software	Contact for quote	Image processing and measurements functions, built-in automatic scripting language, databases and spreadsheets support, graphic representation of output data	No mention.
IN Cell Investigator Software	http://www.biacore.com/high-content-analysis/product-range/Overview/IN_Cell_Investigator/product_information/index.html	GE Healthcare	Contact for quote	Designed for biologists, features such as image stitching, texture transformations, watershed clump breaking, cell tracking, data output	No mention.
JMicro Vision	http://www.jmicrovision.com/	Nicolas Roduit	$0	Object analysis (size, shape, orientation, texture, etc.), object classification, image processing, image rectification	No mention.
NIH Image	http://rsbweb.nih.gov/nih-image/	Research Services Branch of the NIMH	$0	For Macs (Image/J is a program inspired by this one for a PC) , measures area, mean centroid, perimeter, etc. of a user defined region of interest, automated particle analysis, spatial calibration, density calibration	No mention.
PAX-it	http://www.paxit.com/paxit.asp	Midwest Information Systems	Contact for quote	Manages digital images, performs image analysis by detecting	No mention.

				objects by shape, size, color and other criteria, has Materials Science imaging applications, such as coating thickness detection and porosity analysis	
Pixcavator	http://inperc.com/researcher/ResearcherDownload.html	Intelligent Perception	$195	Finds objects, captures them in a contour, and provides data such as size and location	One person performed research to try and recognize integrated text.
PlantVision	http://www.kscape.com/content/plantvision	Knowledge Scape	Contact for quote	Find information about the optimization of mineral processing plants, particles color and size distribution analysis	No mention.
TINA	http://tina-vision.net/	University of Manchester	$0	Collection of codes organized into libraries facilitation the development of image analysis algorithms	No mention.
Tria Image Processing	http://www.quarktet.com/Tria.html	Quarktet	$371	Deconvolution,, has image processing tools	Accepts delimited text files
VisionGauge	http://www.visionxinc.com/software-systems-machines/VisionGauge-main.html	VISIONx Inc.	Contact for quote	High precision measurements and other statistics, counting and sizing objects, image comparison, overlay, and differencing, report generation	No mention.
WipFrag	http://www.wipware.com/wipfrag.php	WipWare	Contact for quote	Uses edge detection algorithms to quantify the size distribution of any material	No mention.

6.0 Acknowledgements

I would like to thank my mentor, Sharon Walter, for providing me with the opportunity to be a part of this project, and for all of the guidance that she gave me along the way. I would also like to thank Alison Stanulevich for her help in editing my final report.

7.0 References

Saveliev, Peter. <http://inperc.com/researcher/ResearcherHome.html>. July 20, 2009.

8.0 Briefing Charts

Introduction to Pixcavator

- Pixcavator is an image analysis software that locates objects in the image and then creates a contour around it which can be edited by the user. An excel sheet is then created, containing data regarding several attributes including size, location, contrast, and roundness.
- This program has meaningful applications in areas such as microscopy, medical image analysis, cell counting, and image manipulation.

Project Relevance to AFRL

- For our purposes, we look to use Pixcavator for integrated text and line drawing information extraction. In the future we hope that this program will be able to aid in the analysis of political cartoons. The research will look to recognize people and facial expressions. This will be done with information of facial components, facial perspective, and other features such as clothing, in combination with the text analysis.
- If the temperament and political climate of communities can be discovered through analysis programs such as Pixcavator in combination with foreign political cartoons, then this technology will be able to help the Air Force predict violent uprisings.

My Work with Pixcavator

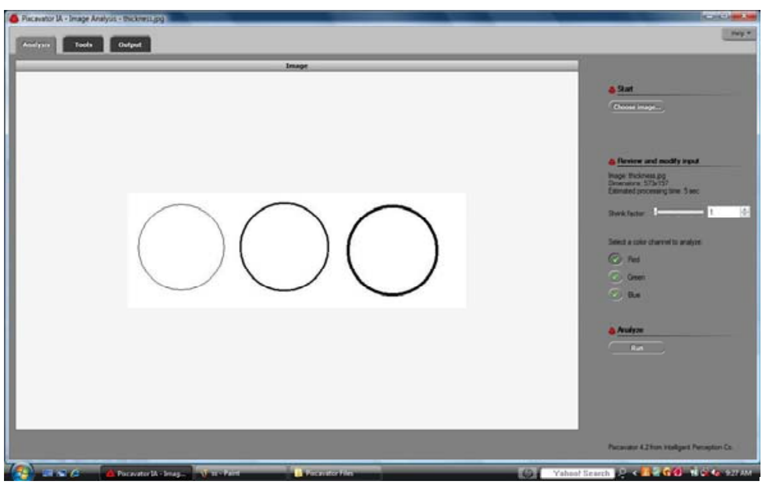
With my time at the lab, I have helped with the beginning stage of research in this area. With this software, my goal was to experiment with the program and to be able to recognize faces in simple line drawings.

Analysis/Tools/Output

The program has three main tabs: Analysis, Tools, and Output.

- Analysis tab
  - Browse your files to find a supported image file to be analyzed.
  - The image appears on the left and it may be shrunk to speed up the analysis process.
  - The RGB channel that you wished to be analyzed may also be chosen here. When choosing the color channel (red, green, or blue) that you wish to be analyzed, that channel will be analyzed separately. This is not important in my project which involved black and white line drawings.
  - Hitting the “run” button starts the analysis, and brings you to the Output tab.

Screen Shot of Analysis Tab

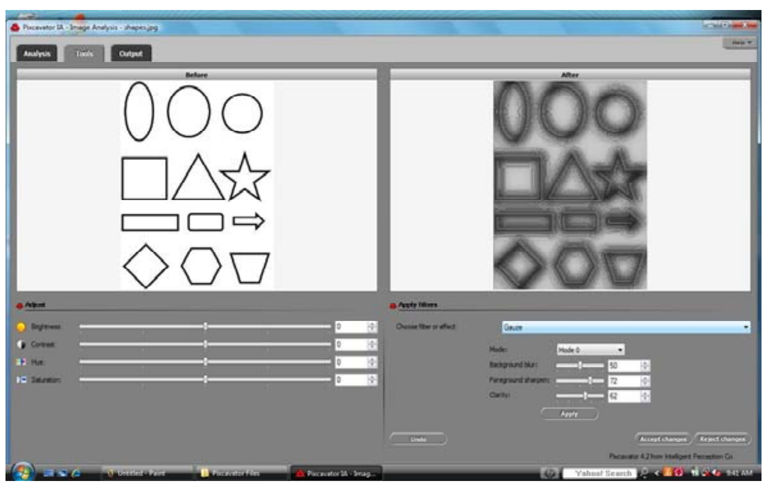


Analysis/Tools/Output

Tools Tab

- Has image-processing options.
- Brightness, contrast, hue, and saturation may all be changed by adjusting the sliders on the left in order to enhance the image.
- There are also several other filters and effects that are mainly used for artistic effect.

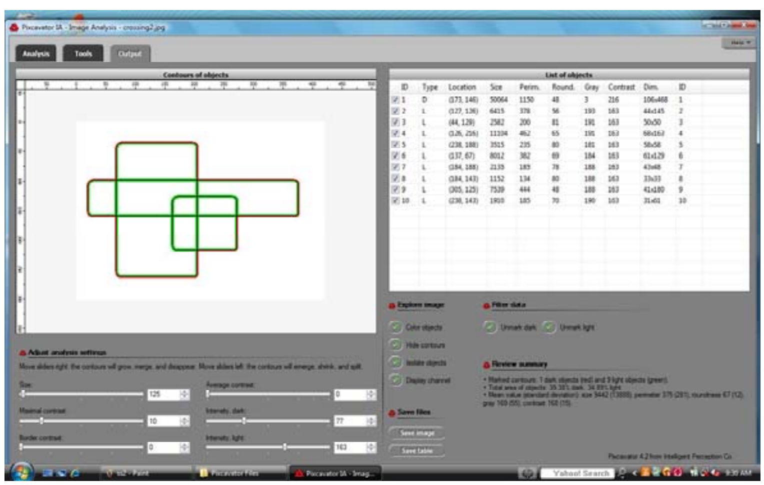
Screen Shot of Tools Tab



Analysis/Tools/Output

- Output Tab
  - Program outlines the dark objects in a red contour and light objects in a green contour.
  - The user can adjust the contours with the sliders below. Thresholds for items such as size and contrast may be adjusted.
  - Once the contours are set, you can look at and export the data that it collected on the selected objects. This data consists of whether the object is light or dark, the object's location of the center of mass, size (area), perimeter, roundness, maximum and minimum level of gray, average contrast, and dimensions.

Screen Shot of Output Tab

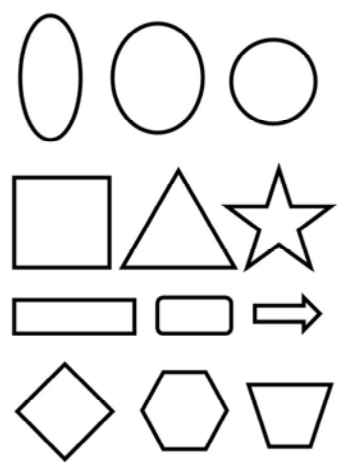


My Work with Pixcavator

- I performed several tests to gain a better understanding of the software and to understand how it can be used to help in our overall project. Each test brought up more questions and launched me into a new experiment in an attempt to find an answer. Some answers were favorable to our research, while other results brought roadblocks. Some of the tests include:
  - twelve different shapes, three simple faces, thickness of a line, overlapping lines, circle with a line extending from it, circle with a line separate from it, shape with excess pixilation, hand drawn circle, hand drawn circle that was not completely closed, hand drawn circle with other shapes crossing and extending from it

Twelve Different Shapes

- After looking over the collected data, it was clear that the roundness data attribute would be helpful in future research. This attribute was a distinguishing characteristic that could aid in recognizing an object as a head. The two most head-like shapes, the circle and the oval, were listed in the data as having the highest roundness, 90 and 88 respectively.
- From looking only at Pixcavator data, and knowing this information, one could easily distinguish that, for example, the object with roundness 25 would not be a head.



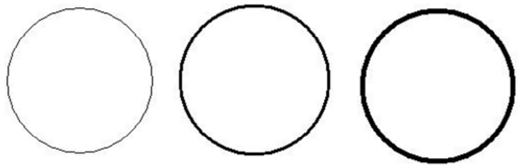
Three Simple Faces

- When analyzed, Pixcavator created twelve contours (around each head, pair of eyes, and mouth), and found data on each of these items. In order to differentiate between the head, eyes, and mouths, scaling and sizes becomes important. In this simple figure, from looking only at the data provided from Pixcavator, each object can be matched up to the object it functions as in the picture.
- The heads and eyes (nine objects) have much higher roundness than the three mouth (40, 36, and 16 versus 80+). Looking at the nine objects of high roundness, the data attributes of size, perimeter, and dimensions easily distinguish between what is a head and what is an eye; the larger object being the head. Location, which provides the center point of the item, allows the user to determine which eyes, mouth, and head belong together.

Three Simple Faces

ID	Type	Location	Size	Perim.	Round.	Gray	Contrast	Dim.	ID
1	D	(333, 135)	674	96	90	5	125	24x24	1
2	D	(520, 153)	562	88	90	6	123	22x22	2
3	D	(108, 110)	304	65	90	8	120	16x16	3
4	D	(566, 153)	561	88	90	6	121	22x22	4
5	D	(543, 169)	24571	586	90	2	124	146x146	5
6	D	(311, 161)	33808	692	89	3	123	173x173	6
7	D	(77, 110)	302	65	90	7	118	16x16	7
8	D	(287, 135)	672	96	91	5	120	24x24	8
9	D	(312, 206)	2741	311	36	4	121	20x135	9
10	D	(99, 175)	1539	347	16	8	117	9x164	10
11	D	(546, 200)	1769	236	40	5	120	17x100	11
12	D	(96, 161)	26274	661	76	3	122	132x197	12

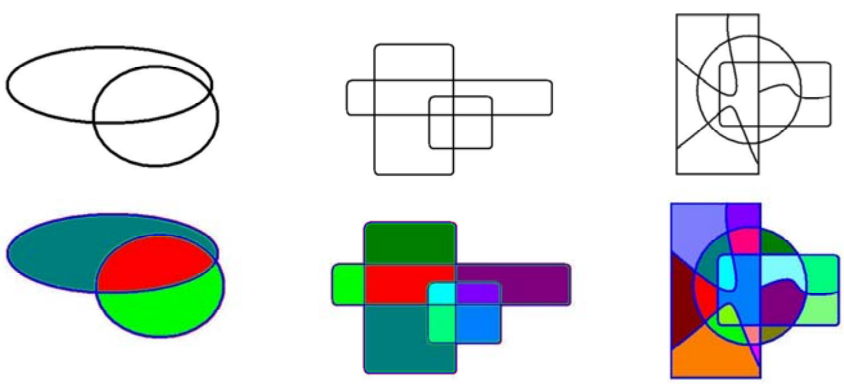
Thickness of Lines



- The software created a dark contour outside of the image, and a light contour inside of the image.
- By comparing the dimensions attribute of the two, it was found that thickness can be discovered by using only Pixcavator.

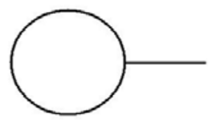
Overlapping Lines

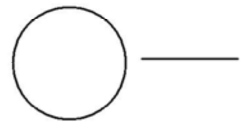
- In images with overlapping lines, one dark contour was created around the entire image, and several light contours were created for each inner piece.
- In a classic Venn diagram type image, there would be one dark contour and three light contours.



Overlapping Lines

- In the image of a circle with a line extending from it, one light contour surrounded the circle and one dark contour surrounded both the circle and the extending line.
- In the dark contour, the location, or center of mass, was shifted slightly to the direction from which the line extended from.

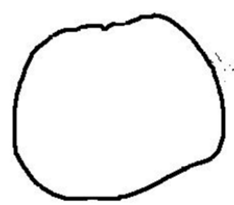




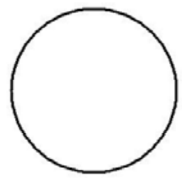
- In the image of the separate circle and line, there was one light contour around the inside of the circle, and two dark contours, one around the circle, and one around the line.
- This shows that Pixcavator does have the ability to detect individual lines.

Excess Pixilation

- In real situations all images will not all be perfectly clean.
- The results of this test were favorable to our research, as the default settings of the size threshold allowed for the program to ignore the excess pixilation so that no unnecessary marks were included in the data.

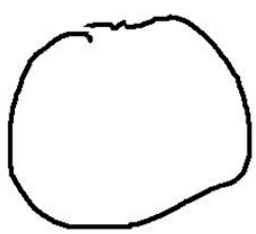


Hand Drawn Circle



- When a hand drawn circle was analyzed, in comparison to a computer generated circle, the results were surprisingly similar. As predicted, the roundness was lower, but not by much. The dark contour roundness was 85 as compared to 90.
- The ability to pin the shape as a circle based on the roundness data was not lost.

Hand Drawn Circle with a Gap



- The data table that resulted from this analysis had no light contour, and a dramatically different dark contour.
- The program recognized the unfinished circle as a line, and therefore all the resulting data was produced as if the object was a line rather than a circle. This significantly affected the dimensions, increased the perimeter, and decreased the size (area). Also, instead of having a roundness of 80+, the most important distinguishing factor of a circle, it had a roundness of two.

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- If the political cartoon artist has more of a sketchy style with gaps in his drawings, it would be difficult to locate faces in Pixcavator.
- I spent time trying to figure out if an algorithm could be applied to this dilemma, but as no endpoints were given, a visible solution has not yet presented itself. There is no way that I have found to tell when the Pixcavator data, which looks like it resembles the data of a line, is actually an unfinished circle.
- While a solution was not found, this was still an important discovery as we now know that this needs to be addressed.

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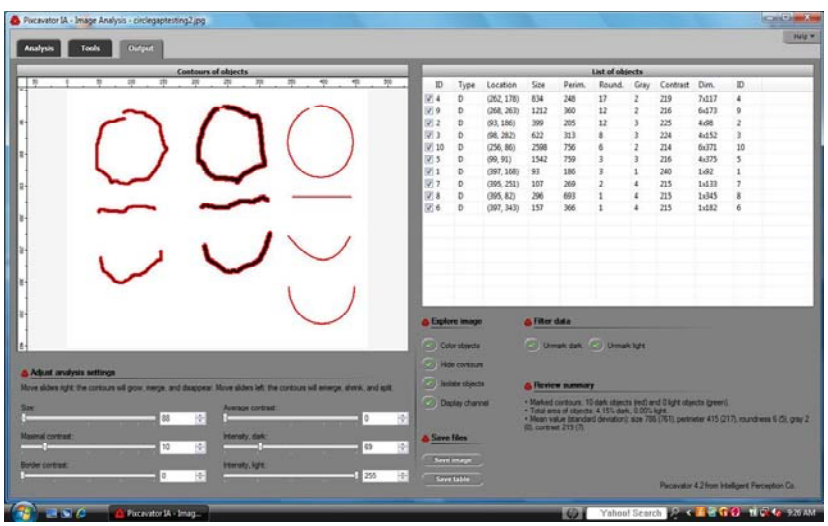
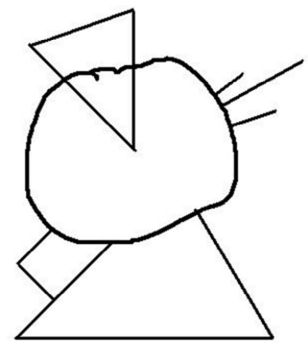


Circle with Other Shapes

- The contours appeared as expected, one dark contour surrounded the entire image including the extending lines, and the light contours appeared inside all of the individual shapes. However, I noticed that the triangle that crossed into the circle significantly decreased the roundness of the circle (roundness was decreased by about 30). This creates a problem for indentifying heads if the character were to have some form of distinguishing trait on their head.



Circle with Other Shapes

- This situation of the triangle inside of the circle caused me to think of Aang, a cartoon character who has an arrow on his forehead. If he were to be analyzed with Pixcavator, the arrow would decrease the roundness of the head as to a point where it would be extremely difficult to gather from the data which object is his head.
- We will have to look for ways around this. For example, in the case of Aang, we could look to locate the arrow instead of a head, and from the coordinates and size of the arrow, the head and other facial features could be located.

Conclusions

- What was learned from this research in regards to finding faces in line drawings:
  - One could theoretically be able to determine if there are faces in a simple image and match up data points to their corresponding facial feature using the following process.
    - After getting a contour around the image, the data should be organized by roundness. An object with about 80+ roundness with a large size and whose dimensions are similar would be a face. Two objects with high roundness, approximately the same y coordinate, around the same size, and much smaller in comparison to the head would be the eyes. An object with coordinates near the eyes on the x scale, but lower on the y scale, while remaining inside of the face would be the mouth.
  - There will be no simple, perfect algorithm that will work for all line drawings.

Future Directions

- While no exact conclusions were made with my time at AFRL, progressions were made and my work can be built upon. Basic work from these simple line drawings will lead to work with detailed faces and pictures.
- We will look towards recognizing real stylized cartoon faces. A cartoon with its own style will be selected and analyzed with a goal of recognizing which shapes are faces, then recognizing the characters that are represented.
- The meta-text (title, artist, text under the drawing) and the integrated text will be relevant and important to understanding what is presented in a cartoon.

Various Other Work

- Researched some current image analysis software that is available in order to gain a better understanding of this area and what such programs are capable of.
- Created a personal twiki page.
- Final Report